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FACTORS AFFECTING IMPROVED AGRICULTURAL TECHNOLOGIES ADOPTION LOGISTIC MODEL IN STUDY AREAS IN EAST SHEWA ZONE, ETHIOPIA

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ABSTRACT

Background: Agricultural production can be increased via intensification, which entails investments in modern inputs and technologies is a better option for increasing agricultural production and improving the livelihoods of farm households. However, there are different factors such as;-demographic, institutional, socio-economic characteristics hindered the adoption of improved agricultural technologies. Thus, this paper investigates the determinants of adoption decisions of multiple agricultural technologies on the basis of cross- sectional household level data generated in East Shewa, Ethiopia.
Methods: The study uses a multi stage sampling procedure to select 400 sample households. Data were collected using a household survey, a Focus Group Discussant (FGD) and key informant interviews (KIIs). Binary logistic regression model was used to analyse the data collected.

Results: The results of the logistic regression model estimate indicate that out of the 13 variables, six were found to have significant influence on the probability of being adopters of improved agricultural inputs at less than 1%, 5% and 10% probability level. These are extension service, access to credit, time of input distribution, price of inputs, farmer's level of motivation and total annual income households' head. We found the importance of promoting multiple and complementary agricultural technologies among rural smallholders.

Conclusions: The adoption of multiple combinations of improved technologies has substantial effects on improvement of the agricultural productivity status among smallholders' farmers. We recommend that improve system of using improved agricultural technologies, better to make uniform, cluster and to reduce the variation observed in rate of application kilogram per hectare among farmers in using improved agricultural technologies especially in teff varieties and chemical fertilizers.

Keywords: adoption, agricultural technologies, smallholders' farmers, Binary logistic model, Ethiopia,

INTRODUCTION

Agricultural production can be increased via extensification (expansion of farmland) or intensification (by using more inputs and technologies per unit of land). Extensification is not a viable strategy for increasing agricultural production in most of the food insecure countries where high population pressure and declining soil fertility are a critical bottleneck. Where land is scarce, intensification which entails investments in modern inputs and technologies is a better option for increasing agricultural production and reducing food insecurities (Tsegaye, 2019; Melesse, 2018; Kelsey, 2011). This option was effectively implemented by several Asian countries since 1970s and was dubbed the ‘green revolution (Agricultural Transformation Agency (ATA), 2018).

Encouraging and facility of improved agricultural inputs technology innovations, is key to increase the productivity through intensification of smallholders farmers. It is widely argued,-that achieving agricultural productivity growth will not be possible without developing and disseminating improved agricultural technologies. In line with this, (Natnael, 2019; Africa Agriculture Status Report, 2015; International Fertilizer Society, 2013) stated that many African governments have been promoting increase use of similar agricultural inputs that may induce farmers to adopt the use of technologies and thereby increase agricultural productivity and improve the income of the smallholder farmers.

Agriculture, particularly of smallholder farmers, is a principal economic activity in Sub-Saharan Africa (SSA) for developing countries that plays a crucial role in growth and development, overcoming poverty and enhancing food security (Bihon, 2015; Department for International Development (DFID), 2014). It is also, the main sector of the Ethiopian economy. It accounts for about 34.1% to the GDP, employs 79% of the population, accounts for 79% of foreign exchange earnings, it is the major sources of raw material and capital for investment and provides large market (Diriba, 2020).

Despite such significant importance and economic contribution, however, until recently in SSA the use of improved agricultural inputs is low. For instance, fertilizer is still only 16 Kilograms (kg) per hectares (ha) compared to the global average of 98 kg/ha (Office Cherifiendes phosphates (OCP), 2015). Not only low application rates, most fertilizer in Africa markets contains only a few major nutrients Diammonium Phosphate (DAP) and Urea, and yet lack a soil specific fertilizer, Nitrogen Phosphorous Sulfur (NPS) that to be deficient in the major soil groups (ATA, 2015; International Fertilizer Development Corporation (IFDC), 2015; Ethio SIS, 2014). Beside this, it still has a very low adoption rate for improved seeds, for instance less than 15% of cultivated areas applied improved seed in 2015/16 (Centre for Dialogue, Research and Cooperation, 2018).

In Ethiopia, different strategies and polices have been devised and being implemented to improve agricultural production and productivity, enhance food security, accelerate agricultural commercialization, value chain promotion, and improve rural livelihoods of smallholders for bringing about the economic growth. These include Agricultural Development Led Industrialization (ADLI) (since 1992), the Sustainable Development and Poverty Reduction Program (SDPRP), a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) to latest launched 5 year Growth and Transformation Plans (GTP-I and II) since 2010/11 as key tenet to achieving the agricultural growth is the adoption of improved technologies together with management practices that will augment yields and increase household incomes for smallholder farmers by realizing its contribution to the country's economy (United Nation Development Programme (UNDP), 2018; Chanyalew *et al.*, 2016; IFDC, 2012).

However, Agricultural production remains poor in performance and slows in progress towards the expected agricultural transformation in Ethiopia (Getachew, 2018 and Bachewe *et al*, *2015*). These argued that the agriculture sector remains poor in performance and slows in progress towards the GTP and Agricultural Growth Program (AGP) goals. Such poor performance can be attributed to very low use of improved agricultural technology inputs. As report of CSA (2018), for 2017/18 production season stated that only 34% adopted full packages of crop technologies:- seed for cereal cropped 15%, oil seeds was 0.8% and 1.6 % of the total pulse and cultivated land under fertilizer was 57%, fertilizers applied 97% kg/ha all crops, this is still far below the recommended 200 kg/ha in Ethiopia.

The share of the agriculture sector to GDP is decreasing overtime partly due to constraints by reliant on rainfall, traditional farming methods (Belay and Mengiste, 2021; Tilahun *et al., 2019*; Beegle *et al., 2016*). As a result, food insecurity and massive poverty are still the major development challenges in the country. For example, based on a $1 per day international poverty line 26.3% of the country's population is estimated to be poor; and in $2 per day standard it increases to 80.7% (National Planning Commission, 2017).

In Ethiopia, different studies have been conducted on the determinants of adoption of agricultural technology; for example (Tamirat and Abafita, 2021; Massresha et al., 2021; Ayenew et al., 2020; Bekele, 2020;Tilahun *et al*., 2019; Worku, 2019; Natnael, 2019; Amare, 2018;Gebrerufael, 2015). Their findings revealed that different factors such as; demographic, institutional, socio-economic characteristics hindered adoption of improved agricultural technologies. However, many of the aforementioned studies show the determinants of single agricultural technology adoption decisions.

But, there were few studies assessed on simultaneous adoption of multiple of agricultural technologies such as Melese et al. (2022) in Ethiopia and Sennuga et al. (2020) in Nigeria. These studies were used already existed data and a small sample. In reality, the majority of the farmers are adopting a single and a combination of technologies. Thus, this paper investigates the determinants of adoption decisions of multiple agricultural technologies by considering adopters of at least two and more technologies in any of one of the crop land and covers a large sample on cross- sectional data.

Finally, adoption of complementary agricultural technologies-improved seeds, chemical fertilizers, pesticides, agricultural credit and agricultural mechanization in country is show to enhance improve poverty status (Biru *et al.*, 2020). However, there is limited empirical study in study area regarding the status of agricultural input supply and determinants of multiple agricultural technology adoption. These scarcity studies have created a knowledge gap on status in zone. Thus, this study systematically investigating factors affecting adoption of multiple improved agricultural technologies, there by contribute new body of knowledge pertinent the domain of agricultural input supply, use and its contribution to the enhancement of smallholder farmers' productivity in the study area, Adama and Adea districts of East Shewa Zone, Oromia regional state, Ethiopia.

OVERVIEW OF RELATED LITERATURE

To increase agricultural production and alleviate poverty, attentions need to be given to technology adoption. Innovation is powerful to enhance agricultural production (Dereje, 2018; Bandiera and Rasul, 2010). Agricultural new technologies are introduced in packages that include several components and use of high-yielding varieties (HYV), the greenhouse technology, genetically modified food, chemical fertilizers, insecticides, tractors and corresponding land preparation practices and the application of other scientific knowledge (Melesse, 2018; Matunhu 2011; Kamruzzaman and Takeya, 2008).

Technology is one of the resources for agricultural production and it is the knowledge and information that permits some tasks to be accomplished more easily, some service to be rendered (Lavison, 2013; Loevinsohn *et al.,* 2012 and Venkatesh *et al.*, 2012). Technology adoption is a complicated task since it varies with the technology being adopted (Challa, 2013). But, in this study, technology adoption refers to the agricultural technologies that farmers use to improve their agricultural productions. That means definition depends on the fact that the farmer is an adopter of the technologies or non-adopter taking values one and zero respectively.

According to Bandiera and Rasul (2010), adoption may be defined as the integration of innovation into farmers' normal farming activities over an extended period. Adoption, however, is not a permanent behaviour. Bonabana (2002) noted that an individual may decide to discontinue the use of an innovation for a variety of personal, institutional, and social reasons one of which might be the availability of another practice that is better in satisfying farmers' needs. Agyeman *et al.* (2014) argued that technology development should be compatible with farmers' preference for step-wise adoption of technological packages, whereby, they adopt the most profitable components first and the riskier one later. Innovation adoption is a time taking process although it induced growth to improve food and nutritional security and alleviates poverty (Kassie et al., 2018; Berihun *et al.*, 2014; Solomon *et al.,* 2012).

The process of adopting an idea or new innovation does not happen as a single unit act, but rather a mental process that consists of at least five stages namely; the awareness stage, the interest stage, the evaluation stage, trial stage and finally, the adoption stage (Cheteni *et al.* 2014; Sennuga and Oyewole, 2020). At the awareness stage, an individual becomes aware of the idea but lacks detailed information about it. At the interest stage, an individual gets more information about it and wants to know more about how it works, what it is and its affordances. At the third evaluation stage, when the user has obtained more information from the previous stages. At the fourth stage, the individual makes a small scale trial of the idea, and requests for more specific information to answer questions. The last mental stage, adoption, is characterized by a large scale adoption of the idea, and most importantly its continued use. For this study modernization theory and diffusion of innovation theory are used to explain the argument in the course of research.

Empirical studies on determinants of improved agricultural technologies adoption

Overall, to explain adoption behavior and factors affecting technology adoption, three paradigms are commonly used. These paradigms are: the innovation-diffusion model, the adoption perception and the economic constraints models. The underlying assumption of the innovation-diffusion model is that the technology is technically and culturally appropriate, but the problem of adoption is one of asymmetric information and very high search cost (Bandiera and Rasul, 2010). The second is the adopters' perception paradigm, on the other hand, suggests that the perceived attributes of the technology condition adoption behavior of farmers. This means that, even with full farm household information, farmers may subjectively evaluate the technology differently than scientists (Caswell, 2001). The economic constraint model contends that input fixity in the short run, such as access to credit, land, labor or other critical inputs limits production flexibility and conditions technology adoption decisions (Challa, 2013).

To understand the effects of factors affecting adoption of improved agricultural technologies, several studies have been undertaken. For example, the study conducted by Ousmane and Nafiou (2019) investigates the determinants of agricultural technology adoption decisions taken by Nigerian farm households such as improved seeds, inorganic fertilizers and plant protection products use the multinomial probit model on cross-sectional data. The results showed that agricultural technology adoption decisions taken by farm households were determined by the age and education level of the farm household head, the size of the farm household, the membership of agricultural cooperative, the number of plots owned, the level of farm household income and wealth, the plot size, the types of soil on the plot, the plots located on the valley and gentle slope, and the land tenure status. The study undertaken by Robin (2016) in Kenya on factors influencing the Adoption of Modern Agricultural Technologies by Small Scale Farmers and from the findings it was concluded that low access to resources, extension services and agricultural research centers and their research products negatively influence the adoption of modern agricultural technologies.

In Ethiopia, Muluken *et al*. (2021) have conducted a study to identify determinants of adoption of improved agricultural technology and its impact on household income in Eastern Hararghe. The logit model result revealed that age, gender, family size, land size, Soil water conservation practices and distance from main market were found significant affecting technologies adoption of improved inputs. Another study conducted by Bekele (2020), to analyse determinants of agricultural technology adoption in Ethiopia, using random effect model. Results of random effect model confirmed that age of the household head, education level, farm size, livestock holding, access to extension services, and credit services, cooperative membership and distance from the market were significantly associated with agricultural technology adoption.

The study of Amsalu et al. (2017) on analyses the determinant of improved modern agricultural technology adoption by farmers in Woliso woreda, Oromia region, Ethiopia used probit model shown that variables such as distance from market, credit accessibility, education level, family size and access to extension service have a positive and significant impact on adoption of High yield variety, while age has a negative and significant impact on their decision. Aman and Tewodros (2016) have conducted a study to identify improved barley adoption intensity determinants in Malga district, Sidama Zone, Ethiopia using Tobit regression model. The Tobit model result revealed that age, farm experience, oxen ownership, membership of cooperative, distance to all weather roads and annual income were found significant affecting the intensity of barley technologies adoption.

The Empirical review of the literature on technology adoption in developing countries as detailed described in above, reveals that the various factors that influence technology adoption can be grouped into the following two broad categories (i) factors related to the characteristics of producers i.e., the farmers; (ii) factors related to the characteristics and relative performance of the program and institutional factors (Melese, 2018; Susan and Leonard, 2016; African Development Bank, 2014; Dercon and Christiaensen, 2011).

The observed gaps were;- the given attention was not much as the problems from concerned bodies and still there are generalization on adoption of improved agricultural technologies.

Analytical framework of the Study

According to different literature and the real world situations, the enhancement of agricultural inputs adoption for increasing agricultural productivity is influenced by demographic, socio-economic, psychological and institutional factors. Therefore, in this study the researcher tries to analyse these relationships, identify the influence of independent variables on the dependent variable. The variables exaggerated were assumed and hypothesized to influence the agricultural input adoption as the most important explanatory variables which are more applicable in rural areas.

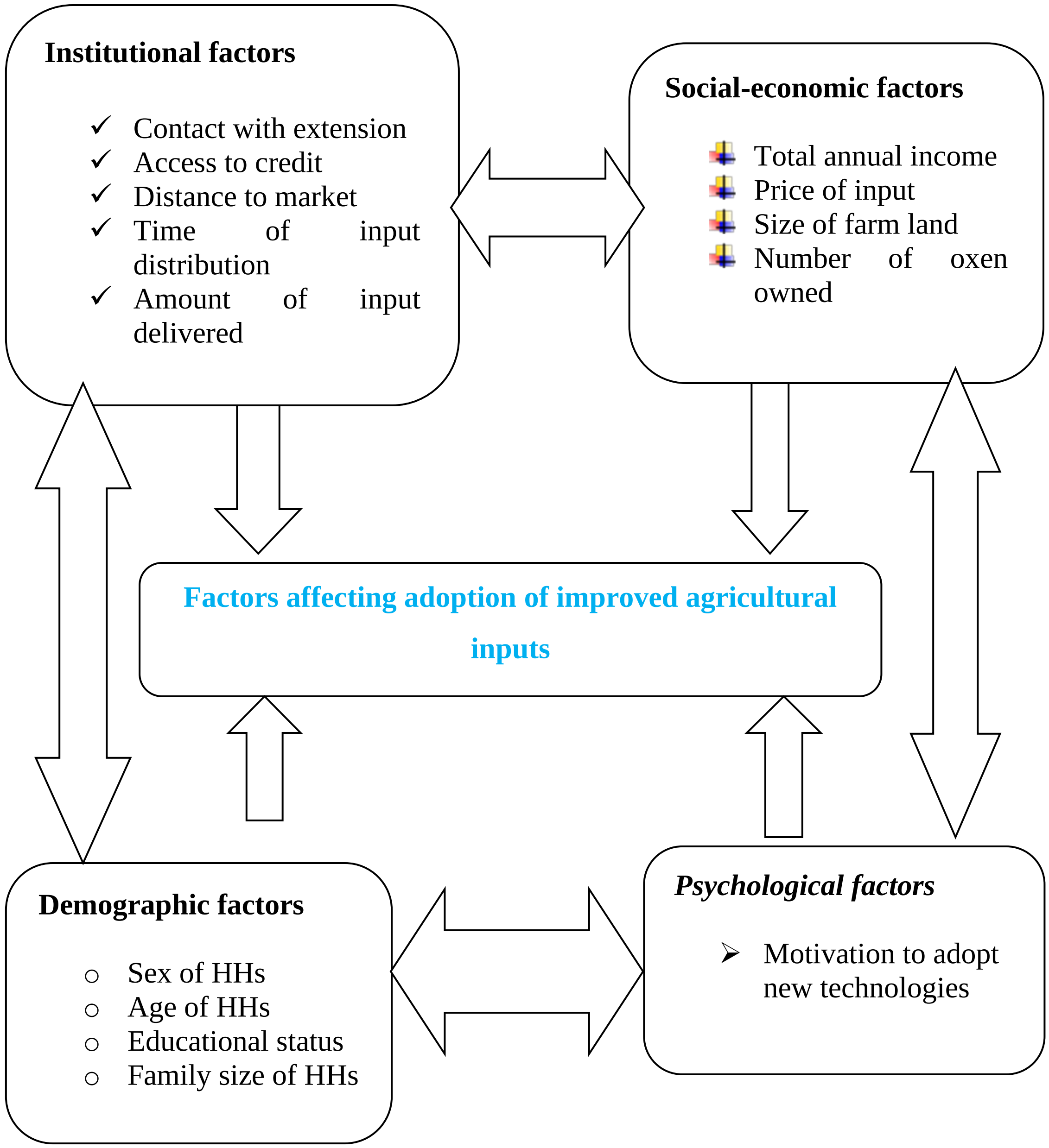

Figure 1: Analytical Framework of the Study, Source (own illustration)

METHODOLOGIES

Sampling method and Data collection

A cross- sectional primary data was collected through structured questionnaire to capture quantitative or qualitative data. In order to discuss the results of the finding, mixed research methods, concurrent embedded design was employed in this study. Researchers who used mixed research methods employ pragmatism research philosophy (Creswell, 2014; Onwuegbuzie and Johnson, 2006). Regarding the sampling procedure, a multi-stage sampling procedure was employed to select the sample households. In the first stage, two districts (Adama and Adea) were purposively selected on the basis of their relative importance in the use of inputs and their accessibility, their potentials for crop production and diversity of agro-climate which represent to the major agro-ecological zones of the East Shewa zone's districts.

This study made references to the following improved crops technologies (improved seeds for teff, maize, wheat and chickpea), chemical fertilizers (DAP, NPS and Urea), agro-chemicals (pesticides, insecticides, herbicides), agricultural mechanization equipment/tools (Tractor, seed planting technology, grain threshing machine, modern grain storage) and agricultural credits (in cash and in kinds). These technologies were chosen following a field scoping survey and mainly used improved agricultural technologies in the study areas.

During the second stage stratification of kebeles according to agro-climate and then 2 rural kebeles Administration (KAs) were selected from each district's using simple random sampling method. Then, in third stage, random sampling method was employed to draw sample households to each KA based on the probability proportional to size (PPS) method. Finally, a total of 400 households' heads (HHs) (200 HHs from Adama district and 200 HHs from Adea district) were selected randomly from sampling frame in the KAs by Kothari (2004) sample size determination formula in 2020/2021 cropping year.

The questionnaire, developed for the research, was pre-tested on a randomly sampled 20 non-sampled households for validity of the data collection instrument and reliability of the collected data. Based on the feedback obtained from the pre-testing exercise, additional orientations were given to the data collectors. Both qualitative and quantitative data were collected through open-ended and close-ended questions of the survey as the main data collection instrument. Alongside, the data collection was supplemented by key informant interview, focus group discussion and secondary data. The questionnaire survey focuses on data pertaining to the socio-economic and demographic characteristics of the respondents, their farming activities, ways of accessing agricultural inputs and factors affecting adoption improved agricultural technologies. Further the researcher closely supervised the process of data collection and provided immediate feedback whenever necessary.

Strategy to data analysis

This study employed descriptive and inferential statistics, and econometric model to analyse data. Data collected through interview schedule were processed, coded, entered into the computer and analysed using Statistical Package for Social Science (SPSS) and STATA software for further analysis. Descriptive statistics, such as mean and standard deviation, tabulation, percentage and frequency were used to present summary statistics of quantitative data pertaining to demographic, socio-economic, institutional and psychological characteristics of sample households. While as inferential statistics, such as Chi-square (χ^2) for quantitative categorical and dummy types of variables and t-test for quantitative continuous types of variables were used to assess the existence of statistically significant differences in observations between improved agricultural technology adopters and non-adopters. Binary logit model was used to analyse constraints affecting adoption of improved agricultural input technologies.

Econometric models

In this paper, regardless of the improved agricultural technology adoption, a farmer was taken as an adopter if he or she uses improved seeds, pesticides, chemical fertilizers, and technology of agricultural mechanization. The dependent variable, technology adoption, has a binary nature taking the value of 1 for adopters and 0 for non-adopters. The binary logit model analysis was as statistical technique used to analyse the factors affecting improved agricultural technologies adoption among variables. According to Maddala (1997) the most widely used quantitative response models are probit (associated with cumulative normal distribution) and logit models (cumulative probability models). In these models, the probabilities are bound between 0 and 1 and they fit well to the nonlinear relationship between the probabilities and explanatory variables.

However, Maddala (1997) and Gujarati (2003) noted that in most application the cumulative normal function (probit) and the logistic functions (logit) are quite similar the main differences being that the logistic model has slightly fatter tails. That is to say the condition probability (pi) approaches zero or one at the slower rate in logit than in probit. Therefore, there is no compelling reason to choose one over the other that depends on personal preference, experiences and availability of software.

Using binary logit decision model random variable Y (dependent variable) takes the value of 1 if the household adopt improved agricultural technologies and 0 otherwise. The probability of a household to adopt improved agricultural technologies depends on vectors of independent variables X_i and a vector of unknown parameter β the vector X_i represents households' demographic, socio-economic, psychological and institutional factors.

The mathematical formulation of binary logit model is as follows:

$$Pi = E(Y = 1/Xi = \frac{1}{1+e^{(\beta_0 + \beta_1 X_1)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

Equation 1 expresses the probability of adopt improved agri-technologies to a household as:

$$Pi = \frac{1}{1+e^{-Z}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

While, the probability for not adopt is expresses by:

$$1 - Pi = \frac{1}{1+e^{Z}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.4)$$

Therefore we can write it as:

$$\frac{Pi}{1-Pi} = \frac{1+e^{Z}}{1+e^{-Z}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.5)$$

Now, (P_i/1-P_i) is simply the odds ratio in favour of the adopter technologies to farmers.

Finally, taking the natural log of equation 4 we obtain

$$Li = \ln \frac{Pi}{1-Pi} = Zi = \beta o + \beta\iota X\iota + \beta 2X2 + \dots + \beta n Xn \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.6)$$

Where: P_i= is the probability of improved agricultural technologies adopter

Zi= is the function of explanatory variables (X_i) which is also expressed as: β_0 is an intercept.

β_1, β2………βn are slopes of the equation in the model.

Li = is the log of odds ratio, which is not only linear in X_i but also linear in the parameters.

Xi= is pre-intervention characteristics.

If the disturbance term $\cup i$ is introduced the logit model becomes

$$Zi = \beta o + \beta\iota X\iota + \beta 2X2 + \dots + \beta n Xn + \cup i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3.7)$$

The major concern of this regression is to predict the probability of adopter to improved agricultural technologies, based on which the hypothesized explanatory variables.

Description and measurement of variables

Adoption in this study refers to a farm household, which used at least one technology such as Improved seed of teff, wheat, maize and Chickpea, inorganic fertilizer (includes DAP, NPS and Urea), Agro-chemicals (insecticides and herbicides), Agricultural mechanization (Tractor, threshing machine, modern grain storage and irrigation pump), Agricultural credit in cash and in kinds and their combinations in any one of the crop fields. Those technologies were selected based on the higher adoption rates in the study areas. Thus, the dependent variable is improved agricultural input technologies adoption by farmers is a dummy variable in the model and it takes 1 if the household is adopter, 0 if none adopter and is estimated using binary logit model. The description and measurement of variables used in the study are presented in Table 1.

Table 1. Description of Variables used in the Study and their Working Hypothesis

NO	Variable Code	Variable Type	Variable definition	Hypothesized r/ship
Dependent variable				
1	Adoption	Dummy	1 if the household is adopter, 0 if none adopter	
Independent variables				
1	Sex of the HH	Dummy	1, if household head is male, 0 otherwise	+ve
2	Age of the HH	Continuous	Age of household in years	+ve/ -ve
3	Educational Level of the HH	Categorical	Educational status of HH head in years of schooling completed	+ve
4	Family size in HH	Continuous	Number of family members in a household	-ve
5	Total Annual Income	Continuous	It is the total annual income in birr household has earned	+ve
6	Input price	categorical	Price of improved agricultural inputs in categorical values	-ve
7	Size of Farm Land	categorical	It is farm land size household hold in hectare (ha)	+ve
8	Number of oxen owned	categorical	Number of oxen Farmers have to plough their land	+ve
9	Access to credit	Dummy	1 if the household access credit service, otherwise zero	+ve
10	Extension Contact	Dummy	1 if the household received extension service and zero, otherwise	+ve
11	Market distance	Continuous	Distance of market in Kilometers from the residence of HH	+ve
12	Time of input distribution	Dummy	1if the household received input on time and zero, delayed	-ve
13	Amount of inputs delivered	Dummy	1 if the household get sufficient inputs and zero, otherwise.	-ve
14	Motivation to receive new technologies	Categorical	Motivational status of farmers using improved agricultural technologies; high, moderate and not motivated at all	+ve

Source: Survey study, 2023

RESULTS AND DISCUSSION

Descriptive statistics results

Results related to demographic, socio-economic, institutional and psychological characteristics are presented in the Table 2. The results, show that there is a statistically significant difference in sex, school years, extension service, access to credit, time of inputs distribution, price of inputs, amounts of inputs required, motivation level, family size and farmland size between adopters and non-adopters of improved agricultural technologies, while the mean value for age and distance to market of respondents were found to be not significantly different between the two groups.

These observations imply that the farm households who used improved agricultural technologies were largely male, educated, and have bigger family size. It is widely acknowledged that male farmers are more likely to adopt agricultural technologies than their female counterparts (Mwungu *et al.,* 2019; Bihon, 2015; Obisesan, 2014). The reasons could be that female farmers have less access to any improved agricultural technologies and other norms and beliefs prevailing in the society which contribute for lower adopter technologies in general. This finding show that farmers who have used technologies have educated compared to those who did not use the improved agricultural technologies. This result is consistent with that of (Yonnas and Seid, 2021; Chowa *et al.,* 2012; Ayenew et al., 2020; Zebib, 2014; Namara *et al.,* 2013). However, this finding contrasts with that of Nata *et al.* (2014), household adoption of soil-improving practices and food insecurity in Ghana.

The study result also showed out that the average family size (in adult equivalent) of sampled farmers of adopters was 6.51 members, and it is higher than the mean family size of non-adopter farmers 6.0 members. This result is consistent with that of (Zegeye, 2021). However, this finding contracts with that of Muluken et al. (2021) the mean family size of respondents was not significantly different between the two groups, adopters and non-adopters. Age of farmers did not significantly affect the adoption of improved agricultural technologies (Hailu *et al.,* 2014; Teklewold *et al.,* 2013). But, this result contrasts with that of Yonnas and Seid (2021), and Hailu et al. (2021) studies, the possible reason could be older age loss of energy and short- planning horizons, as well as being more risk averse for using new technologies. Furthermore, elderly farmers do not have the required labor force to adopt labor- intensive technologies like row planting practices compared to the young people (Kassie et al., 2015).

The second categories of explanatory variables are socio-economic factors such as total annual income, price of inputs, farm land size and number of oxen. According to this result, a statistically significant difference was observed between the adopters and non-adopters in these variables. These results indicate that farm households who owned pair oxen operate a relatively large plot of farm land and had better chance of improved agricultural technologies adoption due to farm households who have oxen can plough more farm land and prepare their land well as well as, they can sow their crop on time which will help them to get better yield and improve their food security and their income and the result is consistent with Dereje (2018), Bihon (2015).

As the price of improved agricultural inputs is expensive, the households' capacity to afford decrease and the price of improved agricultural inputs was negatively related with the use of improved agricultural inputs that approved the previous expectation and match with results of Zebib (2014), Gebrerufael (2015) and Bewket (2011), if price of inputs cheap, there is a rapidly growing amount of users for improved agricultural inputs. Size of land owned by a farmer is found to have positive effect on adoption and matches with findings by Tilahun et al. (2019). Our result contrasts that of Varma (2019), who found that small and marginal farmers are more likely to adopt as compared to large farmers.

Among the five institutional variables considered in this study, all variables were found to have significantly different distribution between the users and non-users of improved agricultural technologies. These are:- extension contact, access to credit, distance to market, time of input distribution and amount of inputs required. This result revealed that Farmers who have frequent contacts with development agents more likely to adopt multiple combinations of agricultural technologies. A number of extension contacts have positively and significantly influenced the adoption. The result is consistent with a prior expectation, positive, in that the frequency access of extension service is a potential force which accelerates the effective adopting of improved agricultural technologies by farmers. This was similar with the studies of Workineh et al. (2020) and Wossen et al. (2015) in Ethiopia.

There is a positive and significant correlation between access to credit service and household decisions to adopt technologies. Results indicate that access to credit has a positive and significant effect on the adoption of improved agricultural technologies. This result is parallel with the previous studies by Tesfaye et al. (2016) and Hailu *et al.* (2015). If market distance is far from the homestead, farmers will face higher transportation cost given poor infrastructure and thereby accessibility of new technology becomes difficult. The result is in line with our prior expectation and consistent with Ayenew *et al.* (2020) and Solomon (2016).

The analysis showed significant association between number time of inputs delivery and adoption of improved agricultural inputs were positive correlation. The result is consistent with a prior expectation, positive, in that inputs of delivery time is a probable dynamism which quickens the active adopting of improved agricultural technologies by farmers. This result is similar to the findings of Workineh *et al.* (2020) and Wossen *et al.* (2015). The investigation shows significant association between amounts of inputs delivered and adoption of improved agricultural inputs were negative correlation. The result is consistent with a prior expectation, negative, in that the accesses of required amounts of inputs are suppressed asset which speed up the effective adopting of improved agricultural technologies by agriculturalists. This result is also correlated to the findings of Tesfaye *et al.* (2016) and Hailu *et al.* (2015).

Adopters who were motivated using new technologies to their agricultural production produce more than the non-adopters. Therefore, there was a positive relationship between adopters of improved agricultural technologies and production motivation status and match with the previous expectation and consistent with study of Zebib (2014). Adopters tend to earn more income per annual than the non-adopters and the mean difference of it is statistically highly significant as shown in below table 2.

Table 2: Descriptive result- Mean values and standard deviations in parenthesis

Independent variables	Adopter (n=134)	Non-adopters (n=266)	t-test/ χ^2 -test (P-Value)
Outcome variable			
Demographic variables			
Male household head[b]	116	229	0.017** (18.43)
Age (years)	52.12 (11.913)	53.23 (10.295)	0.152 (2.062)
Education (years)	77	93	0.000*** (33.845)
Family size (Number)	6.5 (2.254)	6.0 (1.908)	0.014** (6.107)
Socio-economic variables			
Price of inputs (Birr)	92	259	0.000*** (68.54)
Land farm size (ha)	3.24(1.235)	2.94 (1.0)	0.000*** (16.032)
Owned oxen (Number)	120	134	0.000*** (64.26)
Farm income (Birr)	34,149.82 (13819.80	19,741.91 (6072.2)	0.000*** (26.448)
Institutional variables			
Extension service (number)	75	17	0.000*** (123.682)
Market distance (Km)	3.02 (0.74)	3.43 (0.618)	0.387 (0.751)
Credit access[b]	32	14	0.000*** (30.45)
Time of inputs delivered (yes)	45	10	0.000***(66.82)
Amounts of inputs distributed (yes)	119	1	0.000*** (27.16)
Psychological Variables			
Motivation level	23	12	0.000*** (101.02)

*, **, *** indicate statistical significance at 10%, 5% and 1% levels, respectively

b percent (proportion) of the sample

Source: Survey study, 2023

Econometric Results

- Determinants of adopting improved agricultural technologies

The factors that influenced adoption of improved agricultural technologies were examined using the binary logistic regression model. The model was selected based on the justification illustrated earlier under sub-section of econometric models.

So, In order to identify factors that affect adoption of improved agricultural technologies, data gathered from 400 farmers were analysed via binary logistic regression model. Prior to running the logistic regression model, both the continuous and discrete explanatory variables were checked for the existence of multi-co linearity problem. The technique of variance inflation factor (VIF) was employed to detect the problem of multi-co linearity for continuous explanatory variables (Gujarati, 1995). If R_i^2 is the square of the multiple correlation coefficient that results when one explanatory variable (x_i) is regressed against all the other explanatory variables, VIF= $(1-R_i^2)^{-1}$. Likewise, contingency coefficients have been computed to check the existence of multi-co linearity problem for discrete explanatory variables, which assumes a value between 0 and 1.

Value of VIF greater than 10 is often taken as a signal for the existence of multi-co linearity problem in the model. Similarly, the decision rule for contingency coefficients is that if contingency coefficients approach to 1, there is a problem of association between the discrete variables.

Accordingly, values of the VIF for all continuous variables were found to be small (i.e. VIF values less than 10) indicating the data have no serious problem of multi co linearity. As a result, all the continuous explanatory variables were retained and entered into the binary logistics analysis. Similarly, the contingency coefficient which measures the association between various discrete variables based on the Chi-square test, were computed in order to check the degree of association among the discrete explanatory variables or the existence of multi co linearity problem. The decision rule for contingency coefficients states that when its value approaches 1, there is a problem of association between the discrete variables, i.e., the values of contingency coefficients ranges between 0 and 1, with zero indicating no association between the variables and the values close to 1, indicating a high degree of association. Accordingly, the results of contingency coefficient computation revealed that there was one variable has problem of association between the variables, amount of required input and thus; eight of the discrete variables were included into logistic analysis.

Improved agricultural technologies adoption by farmers as a dependent variable, whereby a value 1, is given to households belonging to adopters group and 0 otherwise. Using the 14 explanatory variables (5 continuous and 9 categorical/dummy) for adoption improved in agricultural technologies, the model was estimated by following the maximum likelihood estimation procedure. The parameter estimates and the effects of independent variables on probability of adopting agricultural inputs were analyzed and depicted in below table 3.

The measurement of goodness of-fit of the model shows that the model fit the data well. The likelihood ratio statistics exceeds the Chi-square critical value at less than 1% probability level. This implies that the hypothesis, which says all coefficients except the intercept is zero, was rejected. The value of Pearson Chi-square test shows the overall goodness of fit of the model at less than 1% probability level. The odds ratio implies the ratio of the probability (Pi) that a farmer adopt to the probability (1-Pi) that the farmer is non-adopter. From all sample farmers, 88.3% were correctly predicted in to adopters and non-adopters categories by the model. The correctly predicted adopters and non-adopters categories of the model were 76.9 % and 94 %, respectively.

The results of the logistic regression model estimate indicate that out of the 13 factors included, six of these variables were found to have significant influence on the probability of being adopters of improved agricultural inputs at less than 1%, 5% and 10% probability level, while the remaining seven were less/ not significant in explaining the variations in dependent variable. The variables considered as significant were extension service, access to credit, time of input distribution, price of inputs, farmer's level of motivation and total annual income households' head (Table 3).

Table 3: Determinants of improved agricultural technologies adoption

Variables	Estimated Coefficients (ß)	Standard error	p-value	Odds ratio
Constant	-.686	0.106	0.000***	0.504
SEX	.123	0.468	0.794	1.130
AGE	-.021	0.035	0.312	1.060
EDULEV	-14.631	17.47	0.999	0.000
EXCONTACT	-2.302	0.379	0.000***	0.235
ACCREDIT	0.111	4.379	0.037**	0.320
TIMEINDIST	-1.944	1.040	0.002***	0.143
INPUTPRICE	2.266	0.525	0.000***	9.636
LEVMOTV	-.754	0.257	0.003***	0.809
FLSIZE	0.019	0.021	0.857	1.098
TOTINCOME	0.000	0.000	0.000***	1.000
MRKDST	-.878	8.517	0.275	0.416
FARMSIZE	-.118	0.186	0.527	0.889
OXENOWN	-.026	0.467	0.955	0.974

-2LogLikelihoodRatio	138.15
Pearson Chi-Square (χ^2)	230.04
Correctly Predicted (Count R^2)	88.3
Likelihood of adopter	76.9
Likelihood of not adopter	94.0

***, ** and * significant at 1%, 5% and less than 10% probability level
Source: Model output

Interpretation of Empirical Results of Binary Logistic Model for Adoption of Improved Agricultural Technologies

Access to extension services has been found to be a key aspect in technology adoption. Farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension agents. Extension agent acts as a link between the researchers of the technology and users of that technology. This helps to reduce transaction cost incurred when passing the information on the new technology to a large heterogeneous population of farmers (Genius *et al.,* 2010).

In this study we find that improved agricultural technology users participated more in extension service than the non-users. The sign of this variable is inconsistent with prior expectation and it was negative and statistically significant to influence of adoption improved agricultural technology. But, the study by Mesele et al. (2022) and Akudugu et al. (2012) in Ethiopia and Ghana adoption of modern agricultural technologies shows a positive relationship between extension services and technology adoption respectively. The increase in the intensity of extension services which is significant at less than 1% probability level and diversity of information on agriculture increases the likelihood of adoption.

The odds ratio -2.302 is an indicator for the probability that farmers who have access to extension service on improved agricultural inputs would have adoption rate of improved agricultural technologies inputs decreased by a factor of 0.235. This agrees with the finding of Amsalu *et al.* (2017) and Melese (2018), reported that farmers who had frequent contacts with development agents on agricultural development matters were the ones who got more access to information and encouraged to interact continuously with such knowledge and technology generation and adopt technologies easily.

Diversification of income can also generate an increase in income and reduces the propensity of farming household to fall below the poverty line. Thus income from other sources can positively influence adoption. The result shows a statistically significant gain in household total annual income as a result of using improved agricultural technologies in the study area. This is a significant result implying that adoption of improved agricultural technologies and practices resulted in improved welfare in the study area. This result is consistent with previous empirical results of Bola *et al.* (2012) which shows contribution of income diversification on adoption of rice. Likewise research by:- Cunguara and Darnhofer (2011) in Mozambique shows an improved household income as a result of adopting improved seeds and tractor; Habtemariam *et al.* (2019) in Tanzania, who indicated the positive income effect of adopting fertilizer micro-dosing and tied-ridge technologies; and, Teklewold *et al*. (2013), Hailu et al. (2014) and Wordofa and Sassi (2018) in Ethiopia, who documented a positive income effect of adopting Sustainable Agricultural Practices, and improved seeds and fertilizer, respectively.

It is worth to note that, access to credit is one best option whereby smallholders could be instigated in diversifying their economic base and adopt all imperative yield increasing technologies. It is also believed that access to credit promotes the adoption of risky technologies through relaxation of the liquidity constraint as well as through the boosting of household's-risk bearing ability (Mohamed and Temu, 2008; Simtowe and Zeller, 2006). As this study result the sign of this variable is consistent with prior expectation and it was positive and statistically significant to influence adoption of improved agricultural technologies. The increase in the accessibility of credit service which is significant at less than 5% probability level and diversity of credit on agriculture increases the likelihood of adoption improved agricultural inputs, this similar with the study of Tefera (2014).

The odds ratio 0.11 estimated coefficients is an indicator for the probability that farmers who have access to credit service on agricultural production would adopt improved agricultural technologies increased by a factor of 0.320. The finding is in line with the findings of Amsalu *et al.* (2017), the more farmers have access and source of finance, the more likely to adopt agricultural technologies that could possibly increase crop yield.

The cost of adopting agricultural technology has been found to be a constraint to technology adoption which includes the net gain to the farmer from adoption, inclusive of all costs of using the new technology (Foster and Rosenzweig, 2010). Improved agricultural inputs' price was significantly and positive influence adoption of improved agricultural technologies. It was hypothesized that those farmers who cannot buy since of expensive input price are in most cases difficult to use improved agricultural technology. This is possibly because they have limited economic status and access to modern technologies such as improved varieties of seeds, chemical fertilizers, agricultural machineries, for using in their farm activities. The result of the model was in agreement with the hypothesis at less than 1% probability level and similar with study of Jenkins (2011), it may also difficult for low income farmers to adopt new agricultural technologies.

For instance, the elimination of subsidies on prices of seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programs in sub-Saharan Africa has widened this constraint (Muzari *et al.*, 2013). The odds ratios 2.266 for price of improved agricultural inputs indicate use decision of adoption was increases by a factor 9.636 as the price of inputs increase.

Farmers need motivation in order to take a risk for the newly accepted technologies. Farmers are sensitive to taking risks and they avert risk as much as possible. However, the level of yields is still an important adoption determinant. Crops with lower yield levels are much more unlikely to be produced on the next production. The low production often times associated with the failure of the technology. The finding is consistent Zebib (2014) and Macire *et al*. (2016), the more educated farmers the more motivated to accepted new agricultural technologies, means education can assist farmers accepting and adopting technologies. A similar result was reported by Margaret and Samuel (2015), citing the work of Mignouna et al. (2011), in studying determinants of adopting Imazapyr-Resistant maize (IRM) technology in Western Kenya, they argued that farmers who perceive the technology being consistent with their needs and compatible to their environment are likely to adopt since they find it as a positive investment. Farmers' perception about the performance of the technologies significantly influences their decision to adopt them.

Those farmers who timely access inputs are more users of improved agricultural inputs since they often ready to plant earlier. Thus, timely distribution inputs to farmers are negative and significantly related with household adopting of improved agricultural technologies. This shows that timely got inputs headed households are more users of improved agricultural inputs at significantly higher levels than delayed got inputs, this fits with the finding of Sebsibie et al. (2015) and Tesfaye (2006). This could be because of institutions and economic factors that prohibit farmers from accessing inputs, such as farmers' needs were not identified earlier, sufficient inputs were not provided for the farmers as they required, and more importantly, high prices of inputs since farmers have less cash economy status (Belay and Mengiste, 2021)

Conclusions and Policy recommendation

In Ethiopia, where agriculture is the pillar of the economy, and where severe poverty is the main challenge, reducing poverty is the primary concern. Therefore, boosting production and productivity of agriculture through the use of improved agricultural technology is considered as one solution.

Thus, the main objective of this study was to explain factors affecting the adoption of multiple farm technologies in East Shewa, Oromia region of Ethiopia. The study drew data from a total of 400 farm households who were considered as sample for the study. Moreover, the paper assesses the determinants of adoption by employing binary logit model.

The use of improved teff seed, maize, wheat and chickpea, chemical fertilizers, and pesticides, and agricultural mechanization such as tractor, thresher were identified as the major agricultural technologies adopted in the study areas.

The farmers are using improved agricultural inputs widely and their status may vary from farmer to farmer based on availability, accessibility and lack of awareness of the issues involved. The adoption of multiple combinations of improved technologies has substantial effects in terms of improving the agricultural productivity status of. As a result the majority of sample households' revenues and hence their welfare improved considerably.

The result of the study revealed that farm household's in the study areas decision to adopt improved farm technologies is mainly influenced by factors of socioeconomic, institutional, psychological characteristic of farmers. More specifically, the adoption of multiple agricultural technologies is positively and significantly affected by farmers having credit access, price of inputs and farm income contact. However, the adoption of farm technologies is negatively and significantly affected by contact with extension, delayed time of inputs delivery to farmers and farmer's level of motivation to wards to improved technologies.

Thus, in terms of policy implication, in order to encouraging the participation and motivation of farmers in training centers and providing advisory service to increase the adoption by farm households, agricultural development office, non-governmental organizations, and donor agencies should work in collaborations with the farm households. Specifically, policies for strengthening the system of access to credit and inputs delivery time of farm technologies and prices of inputs should be solved by increasing the availability improved technologies and quality of extension service.

In order to reduce problems of credit access it may call for the need and expansion of microfinance institutions in rural areas where financial constraint is a major challenge for farmers while in adopting technology. Diversify farmer's sources of income to reduce the inflation of price of inputs for better uses of improved technologies timely and effectively which positively influence adoption.

In the study area, improve system of using improved agricultural technologies, better to make uniform, cluster and to reduce the variation observed in rate of application kilogram per hectare among farmers in using improved agricultural technologies especially in teff varieties and chemical fertilizers via facilitating availability, accessibility and affordability of technologies on time.

Lastly, it is important to link up research centers, Universities, farmers and other concerned bodies to strengthened rural technology generation, promotion, and dissemination and adoption interventions.

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